In-cylinder flow

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Abstract

As the emission legislation is getting tougher and tougher for car manufacturers in Europe and in other parts of the world the need for newer and more efficient engines has risen. In-cylinder flow involves different scales and structures as well as moving geometries and unstationary boundary conditions. Additionally, in-cylinder flow has a profound effect on engine emissions and fuel consumption. Therefore, understanding generation of these structures and the effect of compression is essential for reducing engine emissions.

Background

In-cylinder flow can be divided into several distinct phases. The flow enters the cylinder during the intake phase, forming an unsteady hollow jet around the valves. The unsteady jet creates a very turbulent in-cylinder flow field effectively mixing residual gases with fresh air. The incoming jet is also responsible for creating the large scale structures, swirl and tumble. During late part of intake and early compression the small scale turbulence settles while large scale structures remain.

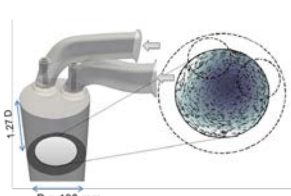
During the second half of the compression any remaining turbulence will be amplified. In addition, swirl and tumble are affect by the changing geometry. Generally, swirl angular momentum is assumed to survive compression while tumble momentum is know to breakdown. If the piston and cylinder head is designed to produce squish (Pressing flow inwards by a rapid reduction of volume close to the cylinder walls), this will produce an organized motion creating turbulence and have dynamical effect on swirl and tumble. During combustion (and definitely from a Diesel spray) turbulence will increase and affect the large scale motions. During the power stroke turbulence is sharply suppressed and at Bottom Dead Center (BDC) most of it has settled.

Focus of this project is to understand the creation and evolution of large scale structures and turbulence from the intake up to start of injection. In addition, identify which parameters can be adjusted to obtain desired flow field.

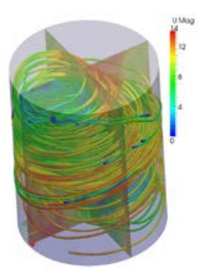
Method

In-cylinder measurements are very difficult due to a number of reasons as well as the difficulty to change the geometry and extract the effect on specific parameters. Therefore, Large Eddy Simulations (LES) has been chosen as the main method in this project.

Initially, flow structures created during intake were studied using LES coupled with Particle Image Velocimetry (PIV) in a steady swirl test rig. Thereafter, the effect of compression on a swirling/tumbling flow has been studied in a simplified engine.



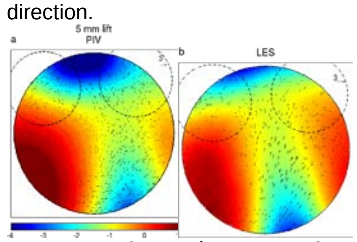
Swirl Test rig



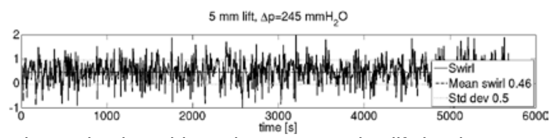
Simplified engine and initial flow field

Results, Swirl test rig

Comparison between LES simulations and PIV experiments show qualitatively good agreement. It is shown that at low valve lifts the fluctuations in swirl is greater than the mean swirl number. In-cylinder turbulence created during intake is axisymmeteric with one dominant direction.



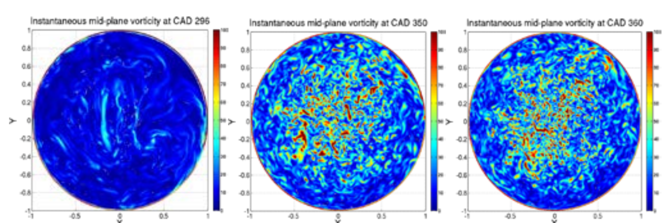
Comparison PIV LES



Fluctuation in swirl number, 5 mm valve lift (PIV)

Results, Compression swirling/tumbling flow

It is found that vorticity-dilatation is responsible for redirecting flow kinetic energy introduced by the piston into small scale turbulence. The conversion is most rapid around the time of maximum dilatation.



Mid plane vorticity magnitude, at different crank angles